THE EFFECTS OF STRYCHNINE ON MENTAL AND MOTOR EFFICIENCY

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I. INTRODUCTION

The present investigation was undertaken to determine the effect of ordinary doses of strychnine, such as are used for therapeutic purposes, on mental and motor efficiency, and to provide material for a comparative study of the effects of strychnine and caffeine on these processes. With the latter purpose in view, the tests and their conditions were made comparable, as far as possible, with those used by Dr. Hollingworth in his recent study.[1] Where changes were made they were to take advantage of the experience gained in the previous study, or were such as were made necessary by the smaller number of subjects.

I am indebted to Professor H. A. Hare of Jefferson Medical College, Philadelphia and to Dr. W. H. McCastline of Columbia University for advice concerning dosage and administration of strychnine; to Professors J. McK. Cattell and R. S. Woodworth for assistance in compiling results; to Dr. H. L. Hollingworth of Columbia University who gave me the benefit of his experience in testing the action of drugs and who arranged the schedule of doses. I am especially grateful to

[1] H. L. Hollingworth, The Influence of Caffeine on Mental and Motor Efficiency. *Archives of Psychology*, No. 22, 1912.

Miss Gladys Tallman, A. M., of Columbia University who acted as subject and experimenter throughout the whole series of experiments.

a. Historical

The effects of strychnine as they are described in works on pharmacology and therapeutics[2] are as follows:

Small doses of strychnine improve the appetite and give a generally strong and hopeful feeling. With a full medicinal dose the respiration is quickened and deepened, the force of the pulse and the blood pressure are increased, but the temperature of the body is not changed except where poisonous doses are given. There is disagreement in regard to its effect on the pulse-rate. However Cushny says that the pulse-rate is reduced and the arterial tension increased. Strychnine exerts its greatest effect on the nervous system where its action is confined almost wholly to the centres in the cord and medulla, although the brain is also somewhat affected.[3] The field of its action is extended by most authors to include every region where simple reflexes may take place. The exact point of its action in the cord is not definitely settled. Some investigators say that it acts neither on the cells of the motor horn nor on

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[2] Roberts Bartholow, *Materia Medica and Therapeutics,* New York, 1889, 431 ff.

G. F. Butler, *A Textbook of Materia Medica, Pharmacology and Therapeutics,* Phila. and London, 1910, 229 ff.

A. R. Cushny, *A Textbook of Pharmacology and Therapeutics, or The Action of Drugs in Health and Disease,* Phila. and New York, 1910, 198 ff.

H. A. Hare, *A Textbook of Practical Therapeutics,* Phila. and New York, 1912, 374 ff.

S. O. L. Potter, *Therapeutics, Materia Medica and Pharmacy,* Phila., 1912, 351 ff.

R. W. Wilcox, *Materia Medica, Pharmacy, Pharmacology and Therapeutics,* Phila., 1904, 394 ff.

H. C. Wood, *Therapeutics: Its Principles and Practice,* Phila. and London, 1902, 207 ff.

[3] Robert W. Lovett, in "An Experimental Investigation of Strychnine Poisoning," (*Jour. of Physiol.,* IX, 1888, 99ff), performed experiments to determine why the effects of strychnine seemed to be localized in the cord, *i.e.,* to determine whether the cord is more susceptible to a given amount of strychnine than the other organs of the body, or whether it has the power of selecting strychnine from the circulation. An elaborate series of experiments seemed to show that when frogs have been given poisonous doses of strychnine and then killed and their organs examined, relatively more of the drug is found in the cord than in the brain or in any other organ of the body. He concluded that the cord has this power of attracting strychnine; but he did not reach any conclusion as to its relative susceptibility to the drug.

the synapses around the motor cells, but that its action consists in the lowered resistance in other synapses, thereby extending the area of the action of the impulses. Others attribute to it an increase in the receptive activity of the sensory centers of the cord, and an increase in the conductive power of both motor and sensory nerves.[4] The action on the cerebrum is said to be very slight. Cases are cited in which fatal doses were taken and the intellect remained unclouded until death. There does not seem to be any direct action on the voluntary muscles, the increase of tone which results being due to an increase in the irritability of the centers in the cord.

The physical symptoms with a full medicinal dose are slight shuddering, sense of constriction of the fauces and jaws, sudden pains like electric shocks passing through the limbs, startings of some of the voluntary muscles, dilated pupils, a meaningless smile, paleness of the face followed by flushing and increased warmth of the surface, and perspiration. Although hearing and smell are increased in acuteness, the greatest effect is noticed in the case of touch and vision. The field of vision is enlarged, especially for blue; and differences in colors can be recognised which ordinarily seem identical.

The effects differ according to the method of administering the drug. Hypodermic injections are the most active, and the most rapid in their effects. Dissolving tablets under the tongue is probably next in efficiency, and gives results in fifteen to twenty minutes. Taking the strychnine into the stomach gives the most tardy results, on account of the slower rate of absorption there. The absorption-time depends on the condition of the stomach, especially the presence of food. It requires from thirty to forty minutes to get results when the dose is taken into the stomach.

The dose usually prescribed varies from 0.01 to 0.05 grain. In emergency 0.1 grain may be given. One-half grain is the smallest dose known to be fatal; but from 0.5 to 1.5 grains is considered by all authors to be fatal. Only a very slight degree of tolerance is developed for strychnine, even after very prolonged administration.

Cushny,[5] in comparing the effects of caffeine, atropine and strychnine, says that each one of the drugs affects the whole

[4] The experimental work of Houghton and Muirhead, "A Contribution to the Study of Strychnine Tetanus," *Medical News,* LXVI., 1895, 612ff, indicates that strychnine acts somewhere between the ganglia of the posterior root and the cells of the motor horn of the cord.

[5] A. R. Cushny, *Pharmacology and Therapeutics,* Phila. and N. Y., 1910, 284-285.

nervous system but not equally. Strychnine affects the lower divisions, the spinal cord and medulla most strongly, showing itself in contractions or twitchings of isolated muscles; caffeine affects the highest functions, the psychical, with little motor effect; atropine holds a middle position and affects chiefly the motor division of the brain and shows itself in excessive coördinated movements, such as walking, talking, etc.

There have been very few researches on the effects of strychnine which have any direct relation to this experiment, and all of these consist of tests of fatigue by means of the ergograph. Rivers[6] mentions only three. Rossi,[7] working with the ergograph in tests lasting one hour, found a decided increase in the amount of work done, but there was no reaction at the end of the hour. Féré[8] also with the ergograph used subcutaneous injections of 8 milligrams of sulphate of strychnine, five minutes before the test began. He found a decided increase in work, followed by a fall below the normal. An initial decrease in the ergogram he explains as due to the effect of the injection process, and not to the drug. P. C. V. Jones[9] carried on a more extended set of experiments on the effects of strychnine on the ergograph curve. The experiments covered a period of fifteen days and were made up of six sets of six ergograms each. Some of the ergograms were made at half-hour intervals and others at hour intervals, so that the effect of the drug was followed in some cases for five and a half hours. The doses, taken by the mouth, were 4.2 milligrams of hydrochloride of strychnine (about one-fifteenth grain) during four days, and 1.8 milligrams, during four days, while on the remaining days the dose was made up of a mixture containing gentian, which could not be distinguished in taste from strychnine. With both doses there was considerable effect. The larger dose gave a rapid rise in the amount of work followed by a gradual fall; but the curve did not fall below the normal until the fifth and sixth, that is, the last two sets of ergograms. The curve for the smaller dose rose less rapidly and fell below the normal only during the last set. His general conclusion is that the effect of strychnine on the amount of work done with the ergograph is a decided increase followed

[6] W. H. R. Rivers, *Influence of Alcohol and Other Drugs on Fatigue.* London, 1908, 110-112.

[7] C. Rossi, Ricerche sperimentali sulla fatica dei muscoli umani sotto, l'azione dei veleni nervosi. *Riv. sper. di. freniat.,* XX, 1894, 442-480.

[8] C. S. Féré, *Travail et plaisir,* Paris, 1904, 297.

[9] P. C. Varrier-Jones, Effect of Strychnine on Muscular Work, *Jour. of Physiol.,* XXXVI, 1907-8, 435-446.

by a decrease. He recognises the cumulative action of the drug, which shows itself in a general lowering of the curve in the second half of the experiment. One subject was used throughout the experiment. It is to be noted that Féré says the increase in the amount of work done is due to an increase in the *number* of contractions; also that Jones says that the increase is *mainly* due to this cause, and only slightly to an increase in the *height* of the contractions. He concludes thus:[10] "Strychnine acts essentially on the spinal cord and medulla; indeed it is remarkable that its action is so clearly defined on this tissue alone, for even in poisonous doses, it does not appear to affect the cerebrum or peripheral nervous structures. Moreover we now know that the drug acts peripherally on the sensory or receptor cells, through which it may be regarded as producing a change whereby impulses can pass through more easily and, instead of being localized to a relatively few efferent nerves, may break down the resistance so as to spread to all efferent fibers supplied from the spinal cord. I conclude then that the effects described are produced by the action of strychnine in diminishing the resistance to afferent impulses on the sensory side of the cord. The after effect may be due either to a poisonous effect of the drug or to pure fatigue."

b. Conditions of the Experiment

The experiments to be reported in this paper covered a period of 38 days, not including a practise period of 10 days by subjects *A* and *B* before the regular work began. During this practice period each test was performed 100 times by *B* and 35 times by *A*. As a result *B* had practically reached the limit of practice, while *A* had at least passed beyond the point of rapid fall in the practice curve. The other subjects had no special practice. Although Rivers, in describing the conditions of fatigue experiments, considers such preliminary practice unnecessary, in these tests where fatigue is not the principal problem considered, preliminary practice removes one complicating factor.

The tests were conducted in a room in the Psychological Laboratory of Columbia University, free from disturbance. The subjects abstained from the use of tobacco, coffee, tea and cocoa during the experiment and for a period of two weeks before it began. They kept as regular hours of retiring and rising as their work permitted. Each kept a general health book in which daily records were made of the state of the

[10] *Loc. cit.*, p. 446.

health, the amount of sleep and any introspections which might seem of value. The subjects knew the purpose of the investigation,—that it was to study the effects of strychnine on their ability in the various tests. However, none knew the arrangement of the doses, so that any effect of the interest in taking a capsule which might have strychnine in it would be as likely to occur on a control day as on a strychnine day.

Seven subjects took part in the experiments; but in the main period covering thirty days, only two took part. A larger number was not available because the tests required such a large amount of the subjects' time. But by taking advantage of the series of experiments conducted by Dr. Hollingworth, on *The Influence of Caffeine on Mental and Motor Efficiency,* these two subjects were made to give a wide range of data. In that experiment there were 16 subjects, 15 of them being divided into four squads. All of the squads took their tests at the same time, but the doses of caffeine were given at different times of the day, and on different days, while one squad received no caffeine, that is, received control doses. In this experiment the schedule of the strychnine doses was so arranged that they were taken at the time of day found to be most favorable in the caffeine tests, namely, mid-afternoon. In addition to this, the doses were given in such series that the various combinations obtained with the larger number of subjects were duplicated with the two subjects at different stages of the experiment. All of the subjects were familiar with psychological work. In those tests in which only two subjects took part, one acted as experimenter while the other was subject. This meant checking up errors in some of the tests and taking the time for each of the tests. No difficulties arose from this method; and it had the special advantage of making a third person to act as experimenter unnecessary.

The strychnine was taken into the stomach in capsule form. Although there are objections to this method, in that the absorption time in the stomach depends on several factors, it seemed preferable to hypodermic injections or to dissolving the strychnine in the mouth. The first method is unpleasant and brings such a prompt reaction to the drug, that its effects may be complicated with the effects produced by administering the drug. Such disturbance was reported by Féré. The latter method is both unpleasant and offers the difficulty of providing a control tablet indistinguishable in taste from the strychnine. The control capsules contained milk sugar, and could not be distinguished in taste and appearance from the strychnine capsules. One capsule, either a control or a strych-

nine capsule, was taken each day. This ignorance of the nature of the dose reduces to a minimum the factors of suggestion, excitement and interest which might be present if the dose were known. The capsules were prepared by a reputable pharmacist and they were independently analyzed by the Columbia College of Pharmacy. They were found to contain the full quantity of pure strychnine sulphate with the slight variation common in such preparations, about 8 per cent. Doses of two sizes were given, one-thirtieth and one-twentieth of a grain. This was to determine the effects of different sized doses, and also to adjust the size of the dose to the body-weight of the subject.

The investigation may be divided into three sections: Experiment A, consisting of the first 28 days with two subjects; Experiment B, consisting of two days of intensive work of 12 hours each, with tests at half hour intervals; Experiment C, with 7 subjects and consisting of two half-days of intensive work. These experiments will be treated in the following sections:

II. Experiment A

This section of the experiment consisted of a series of tests covering a period of 28 days, from February 6, to March 5, inclusive. On each day during this period, subject *A* went through the tests 4 times, at the following hours: 9.30 A. M., 1.30, 3.30 and 5.30 P. M. Subject *B* had one additional test at 8.30 P. M. each day. A capsule was taken each day at 2.45 P. M. This arrangement gave two tests before the dose and two after it should have become effective (three in the case of Subject *B*). Each test lasted about one half-hour, and in the interval the subjects were free to attend to their regular work. The schedule of doses differed for the two subjects and will be given in Table I.

The first four days are recorded as control days for subject *A*.[11] Strychnine days and control days then alternate until Feb. 17, when two control days come together. After this strychnine and control days again alternate until Mar. 1. For subject *B*, the two kinds of doses alternate during the first three weeks, with the result that until Feb. 17, the two subjects receive strychnine on alternate days, while from this date to Mar. 1 they receive it on the same day. Strychnine was then taken by both subjects for three successive days, Mar.

[11] The first two and the fourth day were intended to be control days for *A*, but the subject failed to take the capsule on the third day, which happened to be the first strychnine day.

1, 2, 3, followed by two control days, Mar. 4 and 5. This schedule was arranged by Dr. H. L. Hollingworth and was not disclosed to the subjects until the end of the experiment.

TABLE I

Schedule of Doses for Experiment A

Subject	*A*	*B*	*Dose*	*Subject*	*A*	*B*	*Dose*
Feb. 6..	C	C	1/30 gr.	Feb. 20..	C	C	1/20 gr.
7..	C	S	"	21..	S	S	"
8..	C	C	"	22..	C	C	"
9..	C	S	"	23..	S	S	"
10..	S	C	"	24..	C	C	"
11..	C	S	"	25..	S	S	"
12..	S	C	"	26..	C	C	"
13..	C	S	1/20 gr.	27..	S	S	"
14..	S	C	"	28..	C	C	"
15..	C	S	"	Mar. 1..	S	S	"
16..	S	C	"	2..	S	S	"
17..	C	S	"	3..	S	S	"
18..	C	C	"	4..	C	C	"
19..	S	S	"	5..	C	C	"

The first column in this table gives the date, the second and third columns describe the dose, and the fourth column shows the size of the dose. S stands for a strychnine day and C stands for a control day. For example, on Feb. 13, *A* had a control dose and *B* had a strychnine dose of 1/20 gr.

During this section of the experiment, a capsule was taken each day at 2.45 P. M., two hours and three-quarters after lunch, when under ordinary circumstances the stomach would be empty. The fourth column of Table I shows the size of the dose, 1/30 grain during the first week, and 1/20 gr. during the remainder of the experiment. Thus there were two tests each day before the dose was taken and two after it should have become effective. (In the case of *B* there were 3 after the dose.)

a. Description of the Tests

Eight tests were used: the steadiness test, tapping test, and three-hole test as a measure of motor efficiency; and the color-naming test, opposites test, addition test, cancellation test and multiplication test were used as a measure of mental efficiency. They are the same as the series given in the caffeine test except that the reaction experiment, the size-weight illusion test and the type-writing test are omitted as being the least satisfactory; and the multiplication test was added in order

to give a test of higher mental ability than that afforded by the addition test.

The steadiness test offers the task of holding a metal rod 2.5 mm. in diameter in a hole 6 mm. in diameter for one minute. The subject stands with arms and body free from support during this test. Each contact of the rod with the sides of the hole is recorded on an electric counter. The test is intended to show the general stability of the nervous system. Since the body receives no lateral support, any tremor or twitching of the upper part of the body is likely to be recorded. The test is influenced by a great many uncontrollable factors; but it ought to be of value where the influence of a drug on the nervous system is to be recorded, since any such effect would be expected to show itself in a loss of balance of the delicate muscles. The results of the test are given in the number of contacts made during one minute.

The tapping test measures the time required for the subject to tap a metal plate with a metal rod 400 times. The number of contacts is measured by an electric counter, and the time taken in fifths of a second with a stop-watch. Since the speed of movement of a given set of muscles depends on the nervous discharge to those muscles, a drug which affects the resistance in the nerve centers ought to show its effects in the tapping test. And the most probable effect of such a drug is a change in resistance or conductivity of the nerve substance.

The three-hole test affords a combined measure of accuracy and speed. It consists in inserting the metal rod in each of three holes in a metal plate, until 100 insertions have been recorded on the electric counter. The plate is tilted toward the subject at an angle of 45 degrees; and the holes are located at the corners of an equilateral triangle, about 8 cm. apart. During the test, the subject was seated before the apparatus, with the body unsupported by the table. This test requires considerably more muscular control and coördination than either of the former. The results show the number of seconds required to make the 100 insertions.

The mental tests[12] consisted of a series of association tests,

[12] An experimental study of these tests is reported in Woodworth and Wells, Association Tests, *Psychol. Rev., Mon. Sup.*, 1911, VIII, 5. A discussion of the same tests and the motor tests, with reference to their use for purposes like the present one, will be found in Hollingworth's, Influence of Caffeine on Mental and Motor Efficiency, *Archives of Psychology*, No. 22, 1912.

The method of conducting the tests is that generally used; it follows quite closely the method described by Dr. Hollingworth, so that the procedure will not be given in detail here.

all of them common in psychological work. The simplest one is the color-naming test which measures the speed with which the subject can recognise and name the five most common colors, red, yellow, green, blue and black. These are arranged on a card in the form of a square, in which each color appears 20 times. The time required to name the 100 colors was taken with the stop-watch; and this is the unit in which the results are reported. Four color-orders were obtained by turning the card around 90 degrees at each reading. On account of the long preliminary practice, the subjects were perfectly familiar with the colors and their names, so that the test measured the speed with which the name could be spoken when the color was seen, that is, the speed of the association process. The variation of the colors under differing light conditions made it necessary to conduct this test under electric light. As in all of the association tests, the responses were spoken; and the subject was made to correct his errors before continuing the test.

The opposites test consisted in naming, as rapidly as possible, the opposites of 50 adjectives, taken from the 'moderately difficult' list of Professor Woodworth. These words were arranged in 10 chance orders; and the same list was repeated every two days. The test measured the speed of the association process between two ideas, the subjects having become familiar with the words and their opposites during the preliminary practise period. The tables show the number of seconds required to name the 50 opposites.

The calculation tests, addition and multiplication, afford a still more complicated association process, in that the mental operation is not so definitely predetermined. However, after these tests have been repeated a great number of times, they approach more and more the type of the opposites test, that is, the sight of the number calls up the answer directly. The addition test consisted in the addition of 17 to each of 50 two-place numbers, ranging from 20 to 80, with the numbers ending in 0 omitted. Ten chance orders were prepared as in the opposites test, and the results are given in seconds.

The multiplication test consisted in multiplying each of 25 two-place numbers by 7. The same lists of numbers were used as in the addition test, except that only half of a list was given at one time. This provided 20 arrangements of the 25 numbers, and the same list was repeated every four days.

The cancellation test was used as a measure of the higher mental processes, such as attention, discrimination, etc. The cancellation blank consisted of 1,000 numbers, each of the

TABLE II

EXPERIMENT A

Averages and Differences for Each Test Period

(The figures in the table represent the average, with its probable error, P.E., of all the control days, C, for a given test period, and the average of all the strychnine days, Str., for a given test period. The minus sign in the columns of differences, Diff., indicate that the strychnine test was the faster, except in the steadiness test, where it means a smaller number of contacts. The average differences appear in heavy type.)

Test	*Subject*		9.30			1.30			*Av. Diff. Before Dose*
			C.	*Str.*	*Diff.*	*C.*	*Str.*	*Diff.*	
OPPOSITES.....	A	Av.	38.4	37.3	—1.1	36.3	36.6	+0.3	**—0.4**
		P.E.	1.3	1.0	1.6	0.8	0.9	1.2	
	B	Av.	29.0	28.6	—0.4	28.8	27.8	—1.0	**—0.7**
		P.E.	0.4	0.3	0.5	0.6	0.3	0.7	
COLOR-NAMING	A	Av.	43.4	42.1	—1.3	44.9	41.8	—3.1	**—2.2**
		P.E.	0.6	0.5	0.8	0.9	0.6	1.1	
	B	Av.	36.0	34.7	—1.3	37.4	35.5	—1.9	**—1.6**
		P.E.	0.6	0.4	0.7	0.6	0.5	0.8	
CANCELLATION.	A	Av.	51.8	51.7	—0.1	52.3	52.9	+0.6	**+0.3**
		P.E.	1.3	1.2	1.8	0.5	1.0	1.1	
	B	Av.	46.6	48.1	+1.5	38.9	38.1	—0.8	**+0.4**
		P.E.	1.3	1.5	2.0	0.5	0.6	0.8	
ADDITION.....	A	Av.	67.0	65.9	—1.1	65.8	64.3	—1.5	**—1.3**
		P.E.	1.7	2.3	2.9	1.7	2.0	2.6	
	B	Av.	43.0	40.0	—3.0	41.3	40.3	—1.0	**—2.0**
		P.E.	1.2	0.7	1.7	1.3	1.3	1.8	
MULT.....	A	Av.	63.1	60.3	—2.8	65.4	62.4	—3.0	**—2.9**
		P.E.	2.0	2.2	3.0	1.6	1.9	2.5	
	B	Av.	42.8	41.7	—1.1	43.9	42.8	—1.1	**—1.1**
		P.E.	1.0	1.0	1.4	0.7	0.8	1.1	
TAPPING	A	Av.	59.0	56.4	—2.6	57.4	58.3	+0.9	**—0.9**
		P.E.	1.4	0.9	1.7	0.8	0.9	1.2	
	B	Av.	38.9	38.8	—0.1	38.3	38.6	+0.3	**+0.1**
		P.E.	0.2	0.1	0.2	0.2	0.3	0.4	
THREE-HOLE..	A	Av.	42.7	42.9	+0.2	42.5	43.0	+0.5	**+0.4**
		P.E.	0.4	0.4	0.6	0.4	0.3	0.5	
	B	Av.	40.5	40.7	+0.2	39.7	40.6	+0.9	**+0.6**
		P.E.	0.4	0.4	0.6	0.3	0.5	0.6	
STEADINESS ...	A	Av.	16.2	15.6	—0.6	11.3	12.8	+1.5	**+0.5**
		P.E.	1.6	0.8	1.8	0.9	1.3	1.6	
	B	Av.	17.2	13.1	—4.1	12.2	12.9	+0.7	**—1.7**
		P.E.	1.7	1.1	2.0	1.3	0.9	1.6	

TABLE II—(Continued)

EXPERIMENT A

Averages and Differences for Each Test Period

3.30			5.30			*Av. Diff. After Dose*	*Diff. Due to Str.*
C.	*Str.*	*Diff.*	*C.*	*Str.*	*Diff.*		
36.8	36.9	+0.1	37.9	36.1	—1.8	**—0.9**	**—0.5**
0.8	1.0	1.3	0.8	0.8	1.1		
28.6	29.3	+0.7	29.1	28.7	—0.4	**+0.2**	**+0.9**
0.5	0.7	0.9	0.5	0.6	0.8		
42.7	41.5	—1.2	42.6	43.6	+1.0	**—0.1**	**+2.1**
0.8	1.0	1.3	0.6	0.8	1.0		
37.1	36.4	—0.7	37.7	36.8	—0.9	**—0.8**	**+0.8**
0.7	0.5	0.9	0.7	0.4	0.8		
51.1	53.6	+2.5	54.6	54.5	—0.1	**+1.2**	**+0.9**
0.8	1.1	1.4	1.8	2.2	2.8		
41.1	42.0	+0.9	51.5	49.3	—2.2	**—0.7**	**—1.1**
0.7	0.6	0.9	2.4	2.0	3.1		
66.6	65.6	—1.0	66.6	65.3	—1.3	**—1.2**	**+0.1**
1.8	2.1	2.8	1.6	1.6	2.3		
40.5	39.9	—0.6	42.5	41.6	—0.9	**—0.8**	**+1.4**
1.2	1.6	2.0	1.5	1.6	2.2		
68.2	63.1	—5.1	64.0	63.2	-1.7	**—3.4**	**—0.5**
1.8	2.0	2.7	1.6	1.2	2.0		
43.7	40.8	—2.9	44.0	46.3	+2.3	**—0.3**	**+0.8**
0.9	1.1	1.4	1.1	1.5	1.9		
58.6	59.6	+1.0	58.6	57.9	—0.7	**+0.2**	**+1.1**
1.1	1.1	1.6	0.4	0.9	1.0		
38.3	38.3	0.0	38.9	38.1	—0.8	**—0.4**	**—0.5**
0.2	0.2		0.3	0.2	0.4		
42.6	42.3	—0.3	43.4	42.3	—1.1	**—0.7**	**—1.1**
0.3	0.2	0.4	0.3	0.4	0.5		
40.6	40.0	—0.6	41.8	43.4	+1.6	**+0.5**	**—0.1**
0.7	0.7	1.0	0.6	0.5	0.8		
9.3	10.7	+1.4	12.8	13.9	+1.1	**+1.2**	**+0.7**
0.6	0.5	0.8	1.0	0.9	1.3		
10.1	9.8	—0.3	16.1	17.7	+1.6	**+0.7**	**+2.4**
1.0	0.7	1.2	1.5	0.7	1.7		

digits from 0 to 9 repeated 100 times. One-half of the blank was used in each test, and the results show the time required to cancel a given digit from this list. The difficulty of accounting for errors was avoided by informing the subject that he must cancel five digits in each line. On account of the difference in the legibility of the different digits, only 2, 3 and 5 were used in the latter part of the work. These three have been found to be of about equal difficulty.

b. Discussion of the Data

The data of the entire Experiment A (with the exception of the 8.30 test period) are given in Table II. The first column in the table shows the name of the test, and the second column shows the subject. The rest of the table may be divided into two main parts, the first part containing the data for the 9.30 and 1.30 test periods, that is, the two before the dose was taken; and the second part containing the 3.30 and 5.30 test periods, or those after the dose was taken.[13] Since the 8.30 test was given to only one subject, the data will be given in a separate table (III). The data for this test period show the same results as those in Table II. Under each of the four test periods, there are three columns marked *C, Str.* and *Diff.* In the columns marked *C* are the average times for every test at the given test period on *control days* throughout Experiment A; in the columns marked *Str.* are the average times for every test at the given test period on *strychnine days;* and under *Diff.* will be found the difference in time between this control average and the strychnine average. The number of individual records making up these averages may be seen by referring to Table I, but it is approximately 15. In every case the control average is subtracted from the strychnine average, so that a *minus sign* means that a strychnine day was *faster* than the control day, that is, the average time required to perform the test was shorter; while the plus sign means that the average time was longer on the strychnine day. All the figures represent time except in the steadiness test, where they represent the number of contacts in a given time; and the minus sign means fewer contacts, or a better record on strychnine days. Below each average and each difference, its probable error (P.E.) is given. For example, in the opposites test, at

[13] The results from the 1/30 grain were so similar to those from the 1/20 grain that they have all been combined into the one average shown in the table; and to avoid complication the dose is marked 1/20 throughout. Reference to Table I will show when the 1/30 grain was taken.

the 9.30 period, subject *A* had an average time on control days of 38.4 seconds, with a P.E. of 1.3, and on strychnine days, an average of 37.3 seconds, with a P.E. of 1.0, and the strychnine average for this period is 1.1 seconds faster than the control average, with a P.E. of 1.6.

Following the 1.30 test period there is a column marked *Av. Diff. Before Dose,* which shows the average of the two differences before the dose. Following the 5.30 test period, there is a column containing the average differences after the dose, obtained in the same way.

Since the dose in every case was taken at 2.45 P. M., the first two tests of the day, 9.30 A. M. and 1.30 P. M., would be unaffected by it, so that even on strychnine days the first two tests were control tests. Therefore, there are not only full control days, but the first half of each strychnine day forms a control for that particular day. The value of this check is evident from the table which shows considerable variation in the morning tests from day to day. If conditions were perfect, the difference between control days and strychnine days in the 9.30 and the 1.30 tests should be zero, or at least the difference should be equally divided between plus and minus differences, since the influence to be measured is not then effective.[14] However, as this difference does appear, it must be considered in calculating the difference between control and strychnine days after the dose. Any difference which is to be attributed to the strychnine must be the amount beyond the difference occurring before the dose became effective. That is, a difference of two seconds in favor of the strychnine day at the 3.30 test period would be of no significance if there were also such a difference before the dose was taken. The last column in the table marked *Diff. Due to Str.,* takes this factor into account, and shows the average difference between a control and a strychnine day after the dose, beyond the difference occurring before the dose. The figures in this column are obtained by subtracting the average difference before the dose from that after the dose. As before, the minus sign means that the average of the strychnine days after the dose was faster than that of the control days. The whole process

[14] A study of the data showed that the morning variations were not consistent enough to be the result of a dose of strychnine on the previous day. No reason is given for the fact that the first two tests of strychnine days are so often faster than the same tests on control days, as seen by the predominance of minus signs in these differences. But as most of the differences are within their P.E. the sign is of no importance.

FIG. 1

FIG. 2

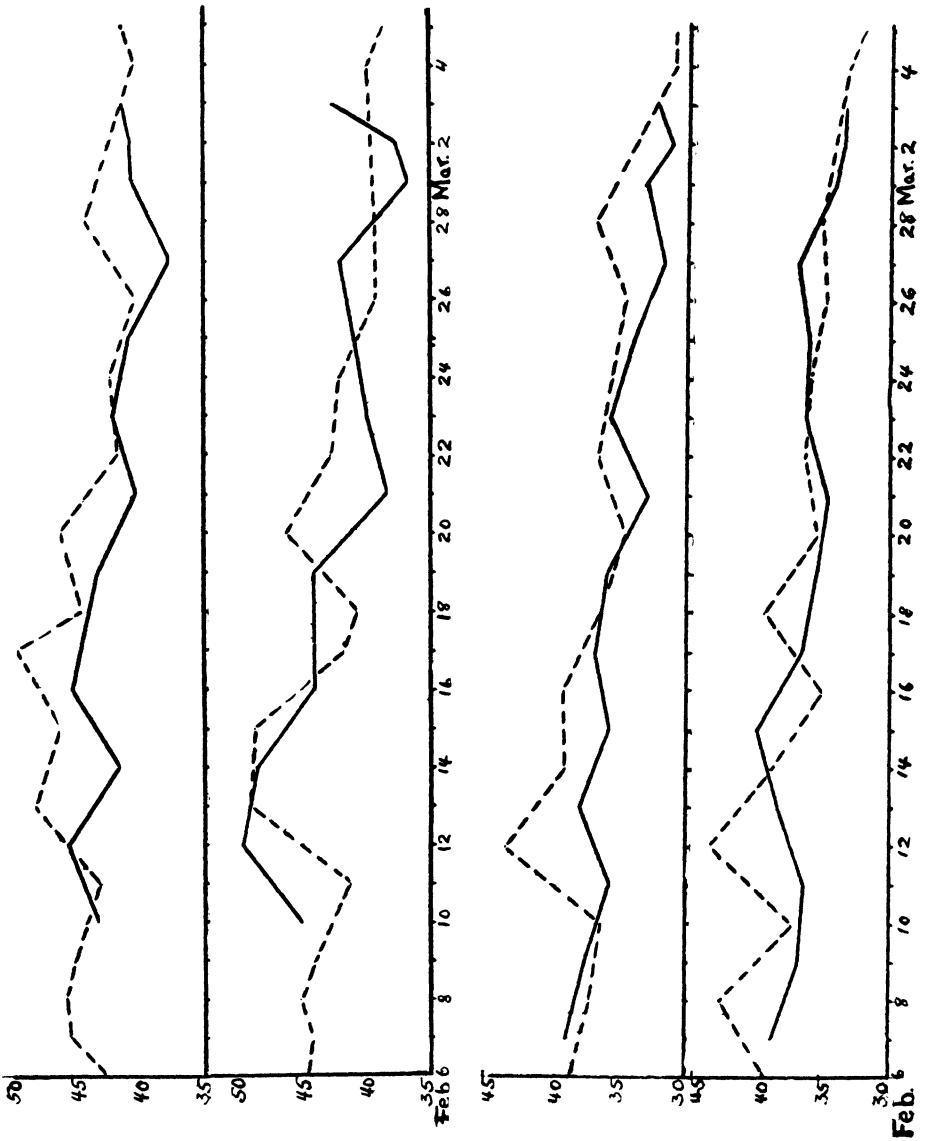

FIG. 1—Curves showing daily records in the Color-Naming Test for Subject *A*.

FIG. 2—Curves showing daily records in the Color-Naming Test for Subject *B*.

[Broken lines represent control days and solid lines represent strychnine days. The upper pair of curves represents tests before the dose and the lower pair those after the dose on control (broken) and strychnine (solid) days.]

by which this last column is derived may be expressed in the form of an equation, which may make the method clearer:

$$\frac{3.30\ (Str.-C)+5.30\ (Str.-C)}{2}-\frac{9.30\ (Str.-C)+1.30\ (Str.-C)}{2}$$
$$=Diff.\ due\ to\ Str.$$

The differences thus found are extremely small,—in 10 cases out of 16, one second or less. In three of the six cases where the difference is above 1 second (Cancellation, Tapping and Three-Hole) the signs are different for the two subjects. That is, the average strychnine time is shorter for the one subject and longer for the other. In the other three cases (Color-Naming, Addition and Steadiness), although the signs are alike for both subjects, the values for one subject in each case are below the probable error.[15] That is, in no two cases are the differences for the two subjects above the P.E. and of like sign. In the Color-Naming test for Subject *A*, the difference due to strychnine is 2.1 seconds. This difference is beyond the probable error and is the most reliable of all those given in the table.

Figs. 1 and 2 show graphically the daily records of subjects *A* and *B* respectively in the Color-Naming test. The curves of this test are selected as typical of all the others. The ordinates represent time in seconds, and the abscissas represent the date of the test. *Broken lines* signify *control* days and *solid lines* signify *strychnine* days. In each case, the upper set of curves shows the average of the two tests before the dose on strychnine days (solid), and on control days (broken). The lower set of curves shows the average of the two tests after the dose on control days (broken), and on strychnine days (solid). Relative difference in the position of the solid line with reference to the broken line in the curves before and after the dose would be due to the drug. Neither pair of curves is significant taken alone, but only when the relative position of the solid line in the two cases is compared. For example, if the solid line in the lower set of curves lay entirely below the broken line and in the upper set intersected a number of times, it would indicate that the strychnine days were uniformly faster than control days. However, the criss-

[15] There is no well-known method available for finding the reliability of these final differences, as they are the differences between the sums of averages; and we cannot calculate the P.E. of the sums of two averages. However, inspection of the reliability of the averages makes it clear that the differences are, in most cases, not far enough above what we might expect by chance to interpret these final differences as the effect of strychnine.

crossing of the two lines before the dose and after the dose shows that there is no influence working only in the afternoon.

Table III gives the data for the 8.30 test period in which *B* was the only subject. The probable errors are higher than for the other test periods, so that the final differences are less reliable. These data serve to corroborate the results shown in Table II.

The conclusion to be drawn from Experiment A is that, for the two subjects tested, ordinary doses of strychnine, taken by the mouth, produce no effect measurable by the tests employed.

TABLE III

Averages and Differences for 8.30 *Test Period*

(Only subject *B* took part in the 8.30 tests. The figures and signs have the same meaning as indicated for table II.)

Test	*C.*	*Str.*	*Diff.*	*Test*	*C.*	*Str.*	*Diff.*
OPPOSITES...	29.2 0.4	28.5 0.4	—0.7 0.6	MULT.....	44.8 1.4	41.6 0.9	—3.2 1.7
COLOR-NAM..	36.3 0.5	35.6 0.4	—0.7 0.6	TAPPING.....	38.9 0.2	38.7 0.2	—0.2 0.3
CANCELL....	41.5 1.3	41.6 0.8	+0.1 1.5	THREE-HOLE	43.2 0.5	44.6 0.3	+1.4 0.6
ADDITION ...	43.1 1.2	42.9 1.1	—0.2 1.6	STEADINESS .	20.8 0.9	22.4 1.5	+1.6 1.7

III. EXPERIMENT B

a. Procedure

The second part of the investigation, to be known as Experiment B, was planned to give a more complete record of the action of strychnine, to discover any very transient stimulation which might have fallen between test periods in Experiment A, and to detect any decrease in efficiency below the normal which might follow as a secondary reaction upon an increase in efficiency. It consisted of a series of tests covering two days in which the two subjects *A* and *B* took part. The same tests and the same technique were employed as in Experiment A. There were twenty-three tests each day, beginning at 8.30 A. M. and following at half hour intervals until 8.30 P. M., with the exception of the 11.30 and 6.30 tests, which were omitted on account of lunch and dinner. As

each test period lasted nearly a half hour, there was practically a continuous series of tests during the twelve hours. Each subject had one control day and one strychnine day. A capsule, either a control or strychnine capsule, was taken each day at 1.45 P. M. This arrangement gave 11 tests before the dose would become effective, and twelve during which the influence of the drug could be observed. A curve of efficiency for each day could thus be established before the capsule was taken, and the effects of the drug could be followed for six and one-half hours.

b. Discussion of the Results

The results of this experiment are given in Table IV. The general plan of the table is identical with that of Table II. The first column contains the name of the test, and the second designates the subject. The remainder of the table is divided into two parts, the first part including the 11 tests before the dose and the second part including the 12 tests after the dose. As the tests were given at half hour intervals, the number of the test and not its time is given at the top of the columns.

The derivation of the figures in this table differs somewhat from that of Table II. Since there were only two whole days included in the experiment, there could be only two tests for each test period; and one of these would be on a strychnine day and the other on a control day. The figures in the table, then, show the difference between these two tests for a given test period, the control day being always subtracted from the strychnine day. Hence a minus sign indicates that the time on the strychnine day was shorter than on the control day. Just as in Experiment A, there will be a certain number of test periods even on a strychnine day, which will be unaffected by the dose, namely, the first 11, since the tests were made before the dose was taken. These 11 tests then serve as a measure of the normal performance of the day. If only chance factors entered, the difference between control and strychnine days in the first 11 tests should be zero or the plus and minus values should be equally divided. At any rate the differences after the dose must be interpreted with reference to these differences before the dose. Here it may be objected that these first 11 tests do not represent a normal performance for the day, since considerable variation may occur later in the day under ordinary conditions. Any constant variation with the time of day will be checked by the complete control day. The establishment of a norm for each day is intended to serve

TABLE IV

EXPERIMENT B. INTENSIVE

Differences Between Strychnine and Control Days

(The figures in this table show the difference between the time of a given test on a control day and on a strychnine day, except in the case of the steadiness test, where the figures represent the difference in contacts. The minus sign indicates that the time on the strychnine day was the faster.)

TEST NO	Subject	*Tests Taken Before The Dose*											*Av. Diff. Before Dose*	*P.E.*
		1	2	3	4	5	6	7	8	9	10	11		
OPPOSITES	A	—1.6	—6.2	+ 0.2	+1.8	— 2.6	— 1.2	— 3.4	—4.0	—0.8	+4.0	—0.6	**—1.3**	0.6
	B	+4.2	+7.6	—1.6	+0.8	+0.2	+3.2	+2.2	—1.6	+1.8	+3.4	—0.2	**+1.8**	0.7
COLOR-NAM. .	A	—3.8	—0.4	+1.2	—2.6	+3.0	+2.0	—7.0	+0.2	—1.2	—3.2	—4.0	**—1.4**	0.6
	B	+4.8	+5.4	+2.4	+1.0	—0.8	—0.2	+0.4	+0.6	+2.4	+1.8	+4.0	**+2.0**	0.4
CANCELLATION.	A	—2.4	—4.4	—21.2	—4.4	—2.2	—24.0	+0.8	- - -	—0.8	—5.0	—3.2	**—6.7**	1.8
	B	—0.4	+5.2	—2.0	—5.2	—2.2	—3.0	+2.2	+1.2	—0.6	+3.3	—2.2	**—0.3**	0.6
ADDITION	A	+0.4	0.0	—0.2	—6.2	+12.2	+7.0	+5.2	—1.8	—4.2	+9.4	+0.2	**+2.0**	1.2
	B	+2.0	—0.8	—1.6	0.0	+3.6	0.0	+2.2	+1.0	—1.0	—0.2	—4.6	**+0.1**	0.4
MULT . . .	A	—1.8	—6.4	+20.0	—4.0	—2.8	+3.6	—11.6	+6.4	—5.6	0.0	+2.4	**0.0**	1.5
	B	—10.2	+0.4	—10.6	+1.6	+3.8	—4.2	—2.4	+7.4	—3.0	+5.8	—6.0	**—2.3**	1.1
TAPPING.	A	+8.6	+3.0	+4.6	—6.4	—2.6	—0.8	—2.4	—0.4	+1.2	—3.8	—6.4	**—0.5**	0.9
	B	—1.2	+0.8	0.0	+1.6	+1.6	+2.2	—0.8	—0.2	+0.8	+0.4	+1.4	**+0.6**	0.2
THREE-HOLE.	A	+0.8	+5.6	+1.8	—2.6	—1.4	—1.2	—0.2	—0.4	—1.6	—2.8	+1.2	**—0.1**	0.5
	B	+1.0	+1.0	+3.4	+3.4	+5.8	+3.4	+2.4	—2.2	+2.8	+2.6	+2.6	**+2.4**	0.3
STEADINESS	A	—9.0	—6.0	0.0	—5.0	—4.0	—12.0	+2.0	—2.0	0.0	—2.0	—6.0	**—4.0**	0.8
	B	+8.0	—2.0	+5.0	—6.0	—6.0	—4.0	—3.0	+4.0	—1.0	+2.0	—3.0	**—0.5**	0.1

TABLE IV—(Continued)

Test No. . .	Subject	Tests Taken After The Dose												Av. Diff. After Dose	P.E.	Diff. due to Str.	P.E.
		12	13	14	15	16	17	18	19	20	21	22	23				
Opposites . .	A	—3.2	+3.6	—0.8	—2.4	—1.8	—3.0	+3.2	—0.6	—3.6	+2.0	—7.4	—7.0	—1.8	0.7	—0.5	0.9
	B	+8.4	—1.2	+1.8	+2.8	+3.8	+0.6	+3.2	+1.4	—0.2	+3.0	+2.6	+2.8	+2.4	0.4	+0.6	0.6
Color-Nam	A	—5.0	+7.6	+8.4	—4.6	—2.4	+0.2	—2.2	+1.4	+0.4	—3.0	+2.6	—2.6	+0.1	0.8	+1.5	1.0
	B	0.0	+5.0	+4.4	+5.8	+2.0	+1.4	+7.2	+6.8	+4.4	+1.4	—7.4	+2.2	+2.8	0.7	+0.8	0.8
Cancell'n. .	A	—10.0	—4.2	—1.8	+11.8	+8.8	+10.6	+10.6	+1.2	—0.6	+19.0	—5.2	—7.2	+2.8	1.9	—9.5	2.4
	B	+7.6	+14.0	—0.4	—1.8	+1.4	—3.0	+7.2	+1.2	+0.8	0.0	—5.4	+3.4	+2.1	1.2	+2.4	1.3
Addition . . .	A	+0.8	+2.8	—5.8	—0.8	+3.6	+1.2	—4.2	—2.6	—0.4	—0.6	—10.6	+0.4	—1.4	0.7	—3.4	1.4
	B	+1.0	+4.4	+0.4	—3.8	—0.8	0.0	—0.4	+3.4	—2.4	—5.6	+5.2	+4.6	+0.5	0.7	—0.5	0.8
Mult.	A	—7.6	—23.6	+2.4	+5.0	+5.8	+7.8	—4.4	+14.4	+2.0	+8.8	—5.0	+11.4	+1.4	1.9	+1.4	2.4
	B	—2.4	—3.6	+2.8	—3.8	—4.0	—2.2	+8.8	—8.4	+4.8	—3.0	—5.2	—0.6	—1.4	0.9	+0.9	1.4
Tapping . .	A	—4.2	—1.2	0.0	—3.6	—0.2	+2.8	—0.2	+0.6	—1.6	+2.6	+1.0	—4.2	—0.7	0.5	—0.2	1.0
	B	+0.6	+0.6	0.0	+1.0	—0.4	+0.2	+0.6	—0.2	+0.4	+0.8	+0.4	+1.6	+0.5	0.1	—0.1	0.2
Three-Hole	A	—0.2	+6.0	—1.8	—3.8	—5.0	+2.4	+1.2	—2.6	—2.8	—0.6	—0.4	—4.6	—1.0	0.6	—0.9	0.8
	B	—1.6	+0.4	+4.8	+3.8	+4.4	+0.2	+4.4	+5.6	+1.2	+3.0	—2.0	+6.4	+2.6	0.6	+0.2	0.7
Steadiness.	A	—7.0	—12.0	0.0	+4.0	+6.0	—3.0	—4.0	—7.0	—4.0	—4.0	—13.0	+2.0	—3.5	1.1	+0.5	1.4
	B	+7.0	+4.0	+5.0	—2.0	0.0	+5.0	+2.0	—5.0	+9.0	+11.0	+6.0	+3.0	+3.8	0.9	+4.3	1.4

as a check on extreme changes in health or general conditions, such as might conceivably occur from one day to another, and I think that it serves this purpose.

Following the records of the first 11 test periods, the average of these differences is given in the column marked *Av. Diff. Before Dose,* and in the next column is the P.E. of this average difference. After test period No. 23, a similar column shows the average difference after the dose, with the P.E. of the average. The next to the last column in the table gives the results due to strychnine and represents the difference between the average difference before the dose and that after the dose. In this case the P.E. of the final value can be calculated and is given in the last column of the table. These figures correspond in meaning with the last column of Table II.

Let us consider the data for the various tests in this table. In the Opposites test the differences for the two subjects are in opposite directions and neither is above its P.E. In the Color-Naming test the difference for *A* is one and one-half times the P.E., while for *B* the difference does not exceed the P.E. In the Cancellation test the differences are quite large and beyond their P.E., but for one subject the strychnine day is faster and for the other it is slower. It is difficult to see how in a test like the Cancellation test strychnine should produce such opposite results in two individuals. I am inclined to attribute these large differences to some irregularity in method or material, especially since the differences were very small in Experiment A, and in the opposite direction in the case of each subject. There *A*'s strychnine time was slower and *B*'s faster. In the addition test *A*'s time is faster for the strychnine day by more than twice the P.E., while *B*'s time is less than the P.E. In Experiment A, the difference for *A* is much less and in the opposite direction, that is, while in Experiment B it is faster, in Experiment A it is slower. In no other case are the differences beyond their P.E., except in the Steadiness test for Subject *B,* where the strychnine record is considerably worse. However, in both experiments for both subjects the strychnine record is poorer, that is, there were more contacts, than in the control record. This is indicated by the positive signs, although the difference is small in all but the one case mentioned. These differences in the Steadiness test are the nearest approach to a difference which may be attributed to strychnine.

An objection might be made to the method of treating the results of this experiment. If strychnine does cause an excitation followed by a depression, by simply grouping the tests

TABLE V

Group Differences Between Strychnine and Control Days

(The column marked *Before Dose* is the average of all the differences between strychnine and control days in all the 11 tests made before the dose was taken. They are the same as the figures in table IV marked *Av. Diff. Before Dose.* The 12 tests after the dose were divided into 3 groups of 4 each and the average difference between strychnine and control days in these groups is shown in the last three columns of the table.)

	Subject		*Before Dose*	*After Dose*		
				Group I	*Group* II	*Group* III
OPPOSITES	A	Av. Diff.	—1.3	—0.7	—0.6	—4.0
		P.E.	0.6	0.9	0.8	1.4
	B	Av. Diff.	+1.8	+3.0	+2.3	+2.1
		P.E.	0.7	1.2	0.5	0.5
COLOR-NAM	A	Av. Diff.	—1.4	+1.6	—0.8	—0.7
		P.E.	0.6	2.7	0.7	0.9
	B	Av. Diff.	+2.0	+3.8	+4.4	+0.2
		P.E.	0.4	0.8	1.1	1.6
CANCELLATION	A	Av. Diff.	—6.7	—1.1	+7.8	+1.5
		P.E.	1.8	2.7	1.4	3.7
	B	Av. Diff.	—0.3	+4.9	+1.7	—0.3
		P.E.	0.6	2.0	1.2	1.1
ADDITION	A	Av. Diff.	+2.0	—0.8	—0.5	—2.8
		P.E.	1.2	1.1	1.2	1.6
	B	Av. Diff.	+0.1	+0.5	+0.6	+0.5
		P.E.	0.4	0.9	0.6	1.9
MULT	A	Av. Diff.	0.0	—6.0	+5.9	+4.3
		P.E.	1.5	4.1	2.2	2.4
	B	Av. Diff.	—2.3	—1.8	—1.5	—1.0
		P.E.	1.1	1.0	2.1	1.3
TAPPING	A	Av. Diff.	—0.5	—2.3	+0.8	—0.6
		P.E.	0.9	0.7	0.5	1.0
	B	Av. Diff.	+0.6	+0.6	+0.1	+0.8
		P.E.	0.2	0.1	0.1	0.2
THREE-HOLE	A	Av. Diff.	—0.1	+0.1	—1.0	—2.1
		P.E.	0.5	1.2	1.2	0.7
	B	Av. Diff.	+2.4	+1.9	+3.7	+2.2
		P.E.	0.3	1.1	0.7	1.1
STEADINESS	A	Av. Diff.	—4.0	—3.8	—2.0	—4.8
		P.E.	0.8	2.5	1.7	1.8
	B	Av. Diff.	—0.5	+3.5	+0.5	+7.3
		P.E.	0.1	1.2	1.3	1.2

before the dose and those after the dose, the excitation and depression effects might be combined in the second group and neutralize each other. In order to show more clearly whether there is such a stimulation followed by a depression, the twelve test periods after the dose have been taken and divided into three groups of four test periods each. Group I, including the first four tests after the dose, represents from one-half to 2 hours after the dose; Group II, including the second 4 test periods, represents from 2 to 4 hours after the dose; and Group III, including the last 4 test periods, represents from 4 to 6 hours after the dose. By comparing each of these groups with the average before the dose, any progressive change in efficiency should appear. The data thus treated are given in Table V. The values with their P.E. under the first column are taken directly from Table IV. The values given under the different groups are derived as stated above.

It is necessary, in determining the true strychnine effect from this table, to compare the values in each of the groups with that before the dose in each case, just as was explained in connection with Table IV. As it is rather difficult to do this by inspection and at the same time judge of the reliability of the differences, Table VI has been compiled to show these differences in each of the groups, after subtracting from each of them the value before the dose. In Table VI, then, only the three groups after the dose are represented, each figure being the difference between *Before Dose* and a given group after the dose. The reliability of each of these differences is indicated by the P.E. Table V might have been omitted except that it would be very difficult to understand the derivation of Table VI without first having seen Table V.

Examination of this table shows that in the Opposites test no differences beyond the P.E. appear. In the Color-Naming test Subject *A* has no significant differences in the different groups, while *B* in the first two has differences about twice the P.E. This is just the reverse of Table IV, for there it was *A* who had the larger differences. In the Cancellation test the differences are still large but for subject *B* in Groups II and III are not much greater than the P.E. In the Addition test we find the same condition as stated in connection with Table IV, that is, the difference is the reverse of that found in Experiment A. No other large differences are found except in the Steadiness test for *B*, and the same was noted in Table IV. The most important thing to be observed in this table is the relation among the three groups. Comparing Group II with Group I we find that in six cases the first

TABLE VI

Values for the Three Groups After the Dose After Subtracting from Them the Average Difference Before the Dose

(This table is obtained directly from table V by subtracting the average difference before the dose from each of the three groups after the dose. It shows the effect of strychnine on each of the tests, the minus sign indicating a better record after taking strychnine.)

Test	*Subject*		*Group I*	*Group II*	*Group III*
OPPOSITES	A	Diff.	+0.6	+0.7	—2.7
		P.E.	1.1	1.0	1.5
	B	Diff.	+1.2	+0.5	+0.3
		P.E.	1.4	0.9	0.9
COLOR-NAM	A	Diff.	+3.0	+0.6	+0.7
		P.E.	2.8	0.9	1.1
	B	Diff.	+1.8	+2.4	—1.8
		P.E.	0.9	1.2	1.6
CANCELLATION	A	Diff.	+5.6	+14.5	+8.2
		P.E.	3.2	2.3	4.1
	B	Diff.	+5.2	+2.0	0.0
		P.E.	2.1	1.3	1.3
ADDITION	A	Diff.	—2.8	—2.5	—4.8
		P.E.	1.6	1.7	2.0
	B	Diff.	+0.4	+0.5	+0.4
		P.E.	1.0	0.7	1.9
MULT	A	Diff.	—6.0	+5.0	+4.0
		P.E.	4.3	2.7	2.8
	B	Diff.	+0.5	+0.8	+1.3
		P.E.	1.5	2.4	1.7
TAPPING	A	Diff.	—1.8	+1.3	—0.1
		P.E.	1.1	1.0	1.3
	B	Diff.	0.0	—0.5	+0.2
		P.E.	0.2	0.2	0.3
THREE-HOLE	A	Diff.	+0.2	—0.9	—2.0
		P.E.	1.3	1.3	0.9
	B	Diff.	—0.5	+1.3	—0.2
		P.E.	1.1	0.8	1.1
STEADINESS	A	Diff.	+0.2	+2.0	—0.8
		P.E.	2.6	1.9	2.0
	B	Diff.	+4.0	+1.0	+7.8
		P.E.	1.2	1.3	1.2

FIG. 3

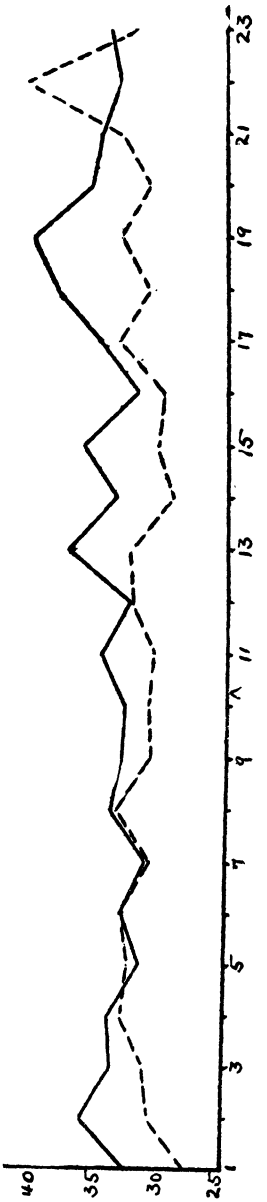

FIG. 4

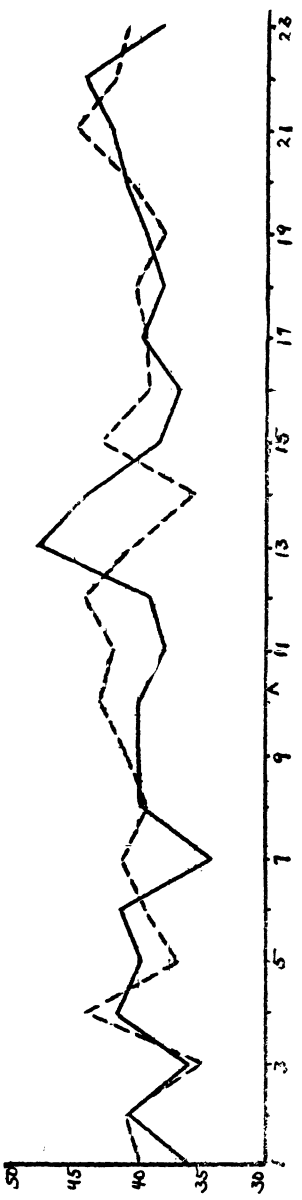

FIG. 3—Curves showing the individual Records of Subject A in the Color-Naming test in the Two Days' Intensive Experiment.

FIG. 4—Curves showing the individual Records of Subject B in the Color-Naming test in the Two Days' Intensive Experiment.

(The broken lines represent the control day and the solid lines the strychnine days.)

group is faster than the second, in three cases there is no difference and in seven cases the first group is slower. Comparing Group III with Group II we find that in eight cases the last group is faster, in one case there is no difference and in seven cases the last group is slower. Hence it is evident that there is no consistent difference among the three groups which would indicate an excitation followed by a depression as a result of the dose of strychnine.

The Cancellation test still remains as one case in which large differences occur in both subjects. It is indeed difficult to understand what function there is which should be so affected in this test and yet which is not included in the other tests.

Figures 3 and 4 show graphically the individual records in the Color-Naming test for subjects *A* and *B* respectively. In each case the *broken line* represents the *control day* and the *solid line* the *strychnine day*. The ordinates show the time in seconds and the abscissas the number of the test period. The carat between period 10 and 11 shows the time at which the capsule was taken. The dose, however, would not become effective until after the eleventh test period. In Figure 3, the curves for A intertwine throughout their course showing no effect from the strychnine. In Figure 4 which represents Subject *B*, the strychnine curve rises above the control curve, representing graphically what was stated in connection with Table IV, that the strychnine time for *B* was slower than the control time. However, inspection of the curve shows that this rise commences several tests before the dose was taken, and hence it must be due to some other influence. This curve reminds us that all the differences appearing in the averages must not be interpreted as purely strychnine effect without constantly referring back to the original data.

It was hoped that in this experiment a condition of fatigue might be reached before the dose was taken, so that the effect of strychnine upon a lowered efficiency might be observed. For the use of strychnine in medicine suggests that it is valuable in raising a lowered activity to its normal, where its influence would be more evident than in stimulating a normal activity to a higher efficiency. In the curves this fatigue would be indicated by a gradual rise of the curve until about the twelfth test period, where a more or less rapid fall would appear. Inspection of the curves however shows that fatigue was not produced by the first eleven test periods.

This intensive study of two subjects supports the conclusion of Experiment A, that strychnine in therapeutic doses does

not produce a heightened efficiency in either the mental or motor functions tested, nor is there any depression noticeable within the time limits of the experiment. The apparent retardation in the Cancellation test occurring in the data of both subjects, and in the case of one subject in two of the other tests, is to be attributed to the influence of other factors rather than that of strychnine.

IV. Introspective Records

The " health book," which each subject kept during Experiments A and B, contained the daily record of his condition with reference to the quality and quantity of sleep, headaches, unusual feelings and any introspections which he chose to record, such as suspicion of having taken strychnine on a certain day, and the like. These records show little that can be attributed to the action of the drug.

Of seven nights in which sleep was reported poor by Subject *A*, five followed strychnine days and two followed control days. This subject took a total of 13 doses of strychnine. Of five nights sleep reported below the average by Subject *B*, three followed strychnine days and two followed control days. This subject took a total of fifteen doses of strychnine. Of four headaches reported by *A*, two were in the afternoon of strychnine days and one in the morning following a strychnine day. Of two headaches reported by *B* both were in the afternoon of strychnine days. There were other isolated reports by both subjects concerning peculiar feelings, such as a queer feeling of contraction in the throat, peculiar feelings in the head such as tenderness, dizziness when the head was moved suddenly, feelings of uncertainty about one's movements, feelings of faintness, sharp pains in the legs, difficulty in fixating the eyes, twitchings in different muscles, etc. But these symptoms did not occur consistently and in many cases they appeared only once or twice during the whole experiment.

During the two days' intensive experiment, it is interesting to note that both subjects on their *strychnine day* reported extreme irritability increasing rapidly toward evening, slight headache, and general disgust with the experiment. On the *control day,* however, both subjects report just the opposite. Neither subject felt tired or irritable and each would have been willing to continue the tests over a longer period. At the close of the strychnine day the idea of doing one more test would have been painful. After the two days' experiment was finished, each subject concluded that his strychnine day must

have been the one on which the work seemed easy and during which there was no fatigue or irritability. But the opposite was the case.

No conclusions are to be drawn from these introspective reports except the negative one that the strychnine produced no marked effect on the character of sleep, nor any constant physical symptoms. In the two days' intensive experiment the strong feelings of fatigue and general irritability accompanying strychnine doses are to be noted. Probably the most significant point in these records is the lack of any disturbances of the general health, from whatever cause, which would complicate the results.

V. Experiment C

a. Description of Tests and Procedure

In the investigation thus far described, two defects may be pointed out. First, it is not safe to draw conclusions from the records of only two subjects. For the persons chosen might be peculiar in that they were not susceptible to small doses of strychnine. However, it may be noted that the experimental work that has been done with strychnine heretofore and whose results have not been questioned, has been done on only one or two subjects. Second, the test with which all previous work has been done, the fatigue test with the ergograph, was not incorporated as a check in the present experiment.

Experiment C was devised as a check upon these two possible defects. Seven subjects, to be known as *A, B, C, D, E, F,* and *G,* all graduate students in the Department of Psychology at Columbia University, took part. (Subjects *A* and *B* are the individuals who acted as subjects in Experiments A and B.)

The experiment consisted of two half-days of 10 test periods each. The first test was given at 1 P. M. and the others followed at half hour intervals until 6 P. M. Each subject had one strychnine day and one control day, and the same methods were used in concealing the nature of the dose as in Experiment A. The capsule was given at 2.15 P. M., so that it would become effective before the 3 o'clock test period. Thus there were 4 test periods before the dose and 6 after the strychnine became effective. The subjects differ considerably in weight, so that it seemed advisable to give doses of 1/30 grain or 1/20 grain, dividing the subjects into two classes, light and

heavy. The schedule of doses, showing the size of the dose and whether the strychnine day was the first or the second of the two, is given below.

Subject	*Strychnine Day*	*Dose*
A	1st	1/20
B	2nd	1/20
C	1st	1/30
D	1st	1/20
E	2nd	1/20
F	2nd	1/20
G	2nd	1/30

None of the subjects except *A* and *B* had any special preliminary practice for this experiment. For this reason, the Color-Naming test and the Tapping test were selected from the list of mental and motor tests, since these are least affected by practice. These two tests were conducted exactly as in Experiments A and B. (Subjects *A* and *B* did not take part in these tests.) Besides these two tests three other measurements were made at each test period, the pulse rate, blood pressure and an ergogram. The pulse-rate was taken at the wrist by palpation and the figures in the table show the rate per minute. The blood pressure was measured with the Tycos Sphygmomanometer by the auscultatory method. Hence the results in the table are in terms of millimeters of mercury. The ergogram was made with the Cattell ergograph. In the ergograms made by previous experimenters, the Mosso ergograph or some modification of it has been used, in which a weight takes the place of the spring of the Cattell ergograph. With the weight type of apparatus, an ergogram consists of the total height the weight is lifted until it can no longer be moved. Such complete exhaustion with the spring type requires hours, so that some limit must be set in making ergograms at frequent intervals. In this case an ergogram consisted of 100 contractions of the index finger at the rate of 2 per second. This rate of contraction was used to induce fatigue as rapidly as possible. But at this rate every subject could make at least 500 contractions, so that the records are not exactly comparable with the complete fatigue records of the other investigators. The ergograms were recorded on smoked paper and the height of each contraction measured. The figures in the table, being differences between control and strychnine days, are calculated from the total distance in millimeters that the finger moved in making each ergogram.

b. Discussion of Results

The results of Experiment C are given in Tables VII, VIII, IX and X. As in Experiment B, the test periods are divided into two parts, those before the dose and those after the dose. The test periods after the dose are then further divided into two groups of three test periods each. Group I represents from one-half to 2 hours after the dose and Group II from 2 to 4 hours after the dose. The figures are derived exactly as in Table V, that is, they are the average differences between the control and strychnine days for each test period.

TABLE VII

EXPERIMENT C

Group Differences Between Strychnine and Control Days

(The columns marked *Before Dose* contain the averages of the differences between the strychnine and the control day, in the first four test periods. *Group I* includes the first three test periods after the dose and *Group II* the second three test periods after the dose.)

Subject		Color-Naming			Tapping		
		Before Dose	After Dose		Before Dose	After Dose	
			Group I	Group II		Group I	Group II
C	Av. Diff.....	+8.2	+7.4	+6.5	+3.2	+0.7	+4.1
	P.E.....	2.5	3.2	0.9	1.2	0.8	2.6
D	Av. Diff.....	+5.1	+0.0	+1.3	+11.6	+9.7	+5.2
	P.E.....	0.7	0.2	1.7	1.6	0.4	1.6
E	Av. Diff.....	+0.4	—5.0	—1.6	+1.8	+3.5	+2.9
	P.E.....	0.9	2.3	0.8	0.5	0.2	0.7
F	Av. Diff.....	—3.0	—2.3	—6.1	—7.8	—5.1	—3.5
	P.E.....	1.7	1.2	0.5	0.8	0.6	2.3
G	Av. Diff.....	—8.8	—6.9	—1.5	—3.8	—0.3	+0.3
	P.E.....	2.2	1.2	1.3	1.2	2.9	1.5

Table VII gives the results in the Color-Naming and Tapping tests for the five subjects, *C, D, E, F,* and *G.* An inspection of the data of the Color-Naming test shows that the effects of practice in these untrained subjects must be taken into account. The plus signs in the data of subjects *C* and *D,* who took strychnine on the first day, and the predominance of minus signs in the case of the other subjects indicates that

the subjects had a tendency to be faster on the second day than on the first. This practice effect cannot be eliminated in the individual cases, as the experiment was conducted, but by taking an average of all the subjects, including those that had strychnine on the first day and those that had it on the second day, the practice effect can be reduced. It cannot be completely eliminated because there were three subjects whose strychnine day was the second and two for whom it was the first day. Thus a tendency for the strychnine average to be faster could be attributed to this remaining practice effect. The averages so calculated in the Color-Naming test are:

Before Dose	*After Dose*	
	Group I	*Group II*
+0.4	—1.4	—0.3

And from these figures we can see that the first group after the dose was 1.8 seconds faster on the strychnine day and the second group 0.7 seconds faster. The probable errors for these figures are high. Comparing these values with those for the Color-Naming test in Experiment A, we find that *A* was 2.1 seconds slower and *B* was 0.8 seconds slower on strychnine days. In Experiment B, Table III, the strychnine time is longer by about the same amount. Taking the individual records for Color-Naming in Table VII, we find that the values for *C* do not exceed the P.E. Subject *D* apparently increases in speed after the dose, but inspection of the original data shows that the seeming increase in speed after the dose is due to the high positive value before the dose, and this is due to the very long times of the first few tests on the first day. After these first few tests the times remain fairly regular. Instead of a marked increase of speed after the dose, the result is due to very slow speed in the beginning of the experiment from lack of practice. *E* shows an increase in speed after the dose of 5.4 seconds; but the P.E. for Group I is high, so that the reliability of the difference is not great. The values for *F* and *G* are to be explained in the same manner. Especially in the case of *G*, there is a gradual increase in speed from 72.2 seconds in the first test to 53.2 seconds in the next to the last test. Since the strychnine day was the second one, that would account for the high negative value before the dose with the reduction in speed after the dose. When all these facts are considered, no strychnine effect is to be attributed to the figures. As this part of the experiment was intended merely as a check on the previous work, the averages given above, in which the practice effect is partly

eliminated, are of most importance. These averages show differences contrary to Experiments A and B and too small to be significant.

The same conclusions must be drawn from the Tapping test records. If the values for the five subjects are averaged, we get the following values:

Before Dose	*After Dose*	
	Group I	*Group II*
+1.0	+1.7	+1.8

Here again the differences are small and the values for the two groups after the dose are practically the same.

TABLE VIII

EXPERIMENT C

Differences in Pulse Rate and Blood Pressure Between Strychnine and Control Days

(The test periods are grouped as in table VI. The figures represent the averages of the differences in pulse rate and blood pressure between the strychnine day and the control day. A minus sign means that the pulse-rate or blood pressure was lower on the strychnine day.)

Subject		PULSE-RATE			BLOOD PRESSURE		
		Before Dose	*After Dose*		*Before Dose*	*After Dose*	
			Group I	*Group II*		*Group I*	*Group II*
A	Av. Diff	+17.0	+12.8	+11.0	+4.5	+1.3	+8.7
	P.E ...	2.4	1.6	0.6	1.5	0.8	0.4
B	Av. Diff	−3.5	−7.8	−1.3	−4.0	+10.0	+3.7
	P.E ...	2.1	1.2	0.2	0.0	0.8	0.4
C	Av. Diff	−13.0	−10.3	−14.0	−2.0	+2.0	+6.0
	P.E ...	1.0	1.1	1.6	2.0	1.3	2.0
D	Av. Diff	−5.0	−6.0	+1.7	0.0	+0.7	+6.0
	P.E ...	0.6	1.0	1.1	1.2	1.1	1.3
E	Av. Diff	+1.7	−3.3	−1.0	−8.7	+1.3	−4.0
	P.E ...	3.9	1.8	1.0	2.4	0.4	2.6
F	Av. Diff	+2.0	−2.0	+2.7	+1.0	+0.7	+3.3
	P.E ...	4.0	2.0	2.2	0.6	1.1	0.4
G	Av. Diff	+4.0	+3.0	+2.3	+2.7	−1.3	−0.7
	P.E ...	2.3	1.0	3.2	1.6	1.2	0.4

The measurement of the pulse rate and blood pressure was included in the series of tests, in the hope that the presence or absence of changes in the physiological processes would indicate whether or not the strychnine had really taken effect in each of the subjects. The knee jerk would undoubtedly have been a valuable measure for this purpose, but without rather elaborate apparatus which could not be quickly attached and removed, or without the assistance of one skilled in making the knee jerk test, the results would have been questionable. The pulse rate and blood pressure had the advantage in that they could be measured quickly and accurately.

TABLE IX

EXPERIMENT C

Pulse-Rate and Blood Pressure Values for the Two Groups After the Dose After Subtracting from Them the Average Difference Before the Dose

(This table is obtained directly from table VIII, by subtracting the average difference before the dose from each of the two groups after the dose. It shows the effect of the strychnine on each of the tests, the minus sign indicating a lower pulse rate or blood pressure after taking strychnine.)

Subject		PULSE-RATE		BLOOD PRESSURE	
		Group I	*Group II*	*Group I*	*Group II*
A	Diff	—4.2	—6.0	—3.2	+4.2
	P.E	2.9	2.5	1.7	1.6
B	Diff	—4.3	+2.2	+14.0	+7.7
	P.E	2.4	2.1	0.0	0.0
C	Diff	+2.7	—1.0	+4.0	+8.0
	P.E	1.5	1.9	2.4	2.8
D	Diff	-1.0	+6.7	+0.7	+6.0
	P.E	1.2	1.3	1.6	1.8
E	Diff	—5.0	—2.7	+10.0	+4.7
	P.E	4.3	4.0	2.4	3.5
F	Diff	—4.0	+0.7	—0.3	+2.3
	P.E	4.5	4.6	1.3	0.7
G	Diff	—1.0	—1.7	—4.0	—3.4
	P.E	2.5	3.9	2.0	1.6

Tables VIII and IX give the data for the pulse-rate and blood pressure tests. The figures in VIII are obtained in

the same way as those in Table V, that is, the column marked *Before the Dose* contains the average difference between the control and strychnine days for the first four tests before the dose. Group I and Group II show the same for the first three and second three test periods after the dose. Table IX shows the values for the two groups after the dose in relation to the value before the dose, or after the difference before the dose has been subtracted from them. The figures are derived from VIII, just as Table VI has been derived from V. These figures would then show the strychnine effect, a minus sign indicating that the pulse rate was slower and that the blood pressure was lower on a strychnine day than on a control day.

An inspection of the pulse-rate records in these two tables shows that in the group immediately after the dose was taken (½ to 2 hours afterward), the pulse-rate of every subject but one, Subject *C*, was reduced, that is, shows a minus value. In the second group (2 to 4 hours after the dose) four of the subjects still retain the slower pulse, while the rate of three has increased. Subject *C* forms an interesting exception. His pulse is normally rather rapid, but on his strychnine day the rate in the first test before the dose was 68 which fell gradually during the afternoon to 56, but continued rather strong. On the control day the first test showed a rate of 81 which dropped during the afternoon to 70. Therefore, although the decrease in the pulse-rate in this case is quite remarkable on the strychnine day, it is not revealed in the table on account of the low rate of the first test on the strychnine day. Thus all of the subjects show a reduction in the pulse-rate in the first group after the dose is taken. The values are small, some of them little beyond the P.E. But in the case of pulse records there is no practice element to be considered, so that the direction of the signs and the smaller values are significant, whereas in the tests previously mentioned they would not be significant.

Tables VIII and IX show that four out of the seven subjects have an increase in blood pressure in the first group of tests after the dose of strychnine, and that all but one, Subject *G*, had an increase in the second group after the dose. Subject *G*, who weighed only 94 pounds, had a very weak pulse and low blood pressure, the latter about 95, so that it was very difficult to make accurate measurements, and I consider them the least reliable of all that were taken. Excepting this case then, there are five out of the seven subjects with a higher blood pressure in the first group of tests after

the strychnine was taken, and all have higher records in the second group after the strychnine was taken. Of the two who have a lower blood pressure after the dose, Subject *F* is lower in the first group by only 0.3 millimeter; and although Subject *A* shows a much lower record in the first group after the dose, this is due to the very high blood pressure in the tests before the dose on the strychnine day.[16] Here, of course, we do not have the factor of practice to consider.

Comparing this evidence for a reduced pulse rate and increased blood pressure after taking strychnine with the statements given in our introduction concerning the physiological effects of strychnine, we conclude that in all of our subjects there is an indication of the influence of strychnine on the circulation. The regulation of the pulse rate and blood pressure is automatic and the centers of their control are located in the medulla, where experimental work has shown that strychnine has an effect.

The results of the Ergograph test are given in Table X, in the form described in connection with the preceding tables. As the figures represent the amount of work done in a given number of contractions, a minus sign indicates that the performance on a strychnine day was *poorer* than on a control day. By comparing the two groups after the dose with that before the dose, we find the following: Four of the subjects, *B, C, D* and *G,* do less work in the first group after the dose than before, while three, *A, E* and *F,* do more. Four of the subjects, *A, C, D* and *G,* do less work in the second group after the dose than before while three, *B, E* and *F,* do more. Now comparing groups I and II, we find that three subjects, *A, D,* and *F,* do less work in the second group than in the first, one subject, *E,* does the same amount in each, and three, *B, C,* and *G,* do more in the second than in the first group. From this brief survey, it is evident that there is no uniform increase or decrease in efficiency in our ergograph test to be attributed to strychnine effect. I do not think the data warrant any more detailed study than this general survey.

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[16] The following figures show the individual records for the blood pressure on Control and Strychnine days for subject *A*:

Control.	117	120	117	117	115	113	112	117	118
Strychnine.	124	122	118	116	115	118	120	127	126

The blood pressure is higher before the dose on the strychnine day than at any time during the control day. If this high value is eliminated from the first two tests, the blood pressure on the strychnine day after the dose will be found to be higher than that for the same tests on the control day. This may be seen by referring to the blood pressure records for *A* in Table VIII.

TABLE X

EXPERIMENT C. ERGOGRAPH

(The test periods are grouped as in table VI, that is, the tests before the dose forming one group, and those after the dose being divided into two groups. In this table the minus sign means *less* work done on the ergograph, and hence a poorer record.)

Subject		*Before Dose*	*After Dose*	
			Group I	*Group II*
A	Av. Diff	—30.8	—28.4	—83.5
	P.E	46.9	10.6	12.3
B	Av. Diff	—100.0	—168.9	—79.3
	P.E	42.9	2.5	3.7
C	Av. Diff	—64.7	—133.7	—108.7
	P.E	90.2	29.2	40.5
D	Av. Diff	+75.0	—103.7	—204.0
	P.E	18.4	11.1	18.3
E	Av. Diff	—53.3	+45.3	+46.3
	P.E	31.1	8.7	14.4
F	Av. Diff	+6.5	+167.7	+150.3
	P.E	47.1	41.7	12.6
G	Av. Diff	+56.0	—47.3	—32.7
	P.E	52.2	28.1	26.1

The data are not offered as proof that strychnine will not influence the ergograph record. The test was employed in the hope that it might give some evidence that the strychnine had taken effect. The material is not sufficient to warrant any conclusion except the negative one in this particular case.[17] The difference in the type of apparatus would probably be sufficient to explain the absence of results which other investi-

[17] Experience with the ergograph in these tests shows that in order to be used to advantage in such work as is here attempted it demands preliminary practice just as much as any of the other tests used. Such details as the taking of a wrong position in the beginning of the ergogram and the attempted shift of position, the stiffness of the muscles resulting after the first one or two ergograms, the learning of tricks of position or movement all tend to cause troublesome variations in the work of the beginner. The subjects in this case were all unpracticed in ergograph work and it is probably this lack of practice which causes the variations in the values of the different groups, and their high probable errors.

gators have found. The spring ergograph cannot induce a state of complete fatigue in 100 contractions, and as the effect of strychnine is given by Féré and Jones to be an increase in the number of contractions before complete fatigue sets in, rather than an increase in the height of the individual contractions, no change would appear in the first 100 contractions.

Experiment C serves to check up the results of Experiments A and B, by showing that the same results are obtained from five additional subjects as were obtained from the first two; it serves as an additional check by showing, in the case of the pulse rate and blood pressure tests, that the strychnine was actually absorbed into the system of all of the subjects and affected the physiological processes controlling the pulse rate and blood pressure.

VI. Conclusion

The conclusion to be drawn from these three series of experiments is a negative one, and one that is contrary to common opinion, which is, that strychnine has a stimulating effect followed by a period of depression. However, it is not contrary to the results of the previous researches which I have been able to find. The tests previously employed have been only those which have measured the rate of onset of fatigue and that in a purely motor process, the Ergograph test. The present experiments were arranged as a test of general mental and motor efficiency and not as a study of fatigue. Moreover, there was no attempt to determine the influence of more than ordinary therapeutic doses of the drug. What effect extremely large doses of strychnine would have on these processes still remains to be determined.

The tests of motor ability were the Tapping test, Three-Hole test and the Steadiness test. Each of these tests necessitates the coördinated movement or balancing of sets of muscles. No definite effect of the strychnine appears in the results of these tests. The nearest approach to a positive result we find in the Steadiness test, where, although the values are extremely small, the signs are nearly all positive, suggesting a poorer record after taking strychnine.

The tests of mental ability including discrimination, attention and association in varying degrees of difficulty show no effect from strychnine, except in one or two isolated cases, where the result might well be ascribed to other causes uncontrollable in the experiments.

Additional check experiments showed that the two subjects

who acted for the major part of the research were not exceptional in their reaction to strychnine, since five other subjects in a short series of tests gave a similar result. Further, the tests of pulse rate and blood pressure showed by the decrease of the former and the increase of the latter after taking the strychnine, that the strychnine must have been absorbed into the system.

Hence, the conclusion is that strychnine in moderate doses taken into the stomach produces no clear cut increase or decrease in efficiency in any of the mental or motor processes studied.

Comparing this conclusion with that of Hollingworth[18] concerning the action of caffeine on these same processes tested in the same manner, we discover the most striking difference. He finds that in the case of the motor tests, small doses of caffeine produced a stimulation in the Tapping and Three-Hole tests, while large doses produced a retardation in the Three-Hole test. Small doses had no definite effect on the Steadiness test, but moderate and large doses produced unsteadiness. In the case of the association tests, Color-Naming, Opposites and Calculation, he finds a stimulation whatever the size of the dose; in the Cancellation test he finds a retardation with small doses and a stimulation with large doses. In no case is there any secondary reaction observed.

A partial explanation of the results of the present investigation and their relation to the caffeine results is offered by Cushny's description of the action of strychnine, caffeine and atropine on the nervous system. (See page 84.) He locates the action of strychnine mainly in the cord and medulla, that of caffeine in the highest or psychic centers of the brain and that of atropine mainly in the centers for coördinated movements. A stimulation by strychnine would tend to produce contractions or twitchings of individual muscles. (This effect was observed in the present experiment, as well as the change in the pulse rate and blood pressure, whose centers are in the medulla.) A stimulation by caffeine would produce a heightened activity of the psychic centers with a confusion of the accompanying mental states, when large doses are given, but no movements would result. A stimulation by atropine would tend to give an excess of coördinated movements such as walking, talking, etc. A further difference between the action of strychnine and caffeine mentioned in the Introduction may be repeated here, namely that in death from

[18] Loc. cit., pp. 164 ff.

strychnine poisoning, the mind remains clear until the end, while caffeine in poisonous doses produces a stupor.

The mental processes then, those which depend on the function of the cortical centers, would not be affected by strychnine. The motor processes which would depend on the center in the brain for the coördination of muscular movements would be affected only in so far as the twitchings and involuntary movements of the muscles would disturb the coördination of muscle groups. These involuntary movements did affect the Steadiness test in some cases, but the twitchings were so infrequent that their influence could be easily hidden by other variations in the subjects' behavior.

Numerous instances have been reported recently where strychnine has been taken by individuals about to enter physical contests and mental tests such as college examinations, in order to increase their ability. In the former case strychnine might be of value in postponing the onset of muscular fatigue. In the latter case, however, where the psychic centers are concerned, and where the processes of association, attention and discrimination are involved, the results of this research would indicate that strychnine is of no value. The influence of suggestion where such a powerful drug as strychnine is concerned is tremendous, and the writer believes that if this suggestion factor were eliminated, those mental operations and all other processes where popular opinion attributes such power to strychnine, would not be affected either one way or the other by ordinary doses of strychnine.